

BigBOSS: Guiding, Focus and Alignment System

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BigBOSS

BigBOSS is a proposed DOE-NSF Stage IV ground-based dark energy experiment.

The BigBOSS science goals include

1. Measure the baryon acoustic oscillation signal

2. Measure the growth of structure

To achieve these science goals, the BigBOSS survey will

• Map large scale structure using a red-shift survey

Depth: $0.2 \leq z \leq 1.7$.

Targets: Emission lines galaxies (ELGs) and luminous red galaxies (LRGs).

• Measure the Ly- α forest between $1.9 \leq z \leq 3.4$

BigBOSS Instrument

Some key information and the BigBOSS experiment include:

• Located at the 4 m Mayall telescope at Kitt Peak near Tucson,AZ

• Three degree field of view

• Prime focus location with optical corrector lenses

• ~1m focal plate with 5,000 robotically actuated optical fibers

• Each fiber will feed a three arm spectrograph covering $340 \text{ nm} \leq \lambda \leq 1060 \text{ nm}$

• Measure 14,000 square degrees using 500 nights over 5 years.

Guide, Focus and Alignment System

The success of the BigBOSS experiment depends upon the total optical throughput of the BigBOSS instrument. Throughput depends on source brightness, atmosphere, telescope, optics, optical fiber alignment, fiber transmission and sensor response.

The guide focus and alignment system improves total optical throughput. Its functions include

• Field acquisition for each pointing

- Full frame image of the field on each guide sensor
- Matches the fields to star catalogs
- Determines guide stars to use
- Determines the desired location of each guide star at a sub-pixel level
- Provides a guide error signal to the telescope control system to
 - * Correct initial pointing on the sky
 - * Maintain correct pointing during science exposure

• Provides 1 Hz guide signals to the telescope while collecting science data

• Provides corrections to the hexapod system between each exposure

- Measures the wave-front (error) using intra/extra-focal sensors several times per exposure.
- Sends focus/alignment corrections to the hexapod
 - * Decenter (x,y) from combination of wave-front error and guide data
 - * Defocus (z) from wave-front error
 - * Tip and tilt (rotation about x and y) from wave-front error
 - * Rotation about z from combination of wave-front error and guide data

Star Counts

Sensor Selection

Manufacturer Model	Area [†] Area [†] [cm ²]	Dark Current at 25 C [e ⁻ /pixel s]	Read Noise [σ _{e⁻}]	Nom. Rate [MHz]	Pixels H x V [†]	Pixel Size [μm]	Notes
Kodak KAF09000	13.4	5	7	3	3056 x 3056	12	1 channel
Kodak KAF3200E	1.5	20	7	1	2148 x 1510	6.8	Small
e2v ccd230-42	9.4	20	8.5	1	2048 x 2064	15	
e2v ccd230-84	37.7	20	8.5	1	4096 x 4112	15	Large
Kodak KAF1602E	1.2	50	15	10	1538 x 1024	9	Small
Kodak KAF6303	5.1	50	15	4	3072 x 2048	9	1 channel
Kodak KAF16801E	13.6	50	15	2	4096 x 4096	9	1 channel
Fairchild ccd3041	9.4	209	6.5	1	2048 x 2048	15	Dark
Kodak KAF1301E	3.4	238	15	1	1280 x 1024	16	Dark
e2v ccd47-10	1.9	274	6	1	1056 x 1027	13	Small
Atmel TH7899M	8.2	304	5	1	2048 x 2048	14	Dark
e2v ccd30-11 OE	1.8	503	12	1	1024 x 256	26	Dark/Small
e2v ccd42-40	7.6	501	8	1	2048 x 2048	13.5	Dark
Kodak KAF1001E	6.0	550	13	1	1024 x 1024	24	Dark
e2v ccd77-00	0.4	703	6.5	1	512 x 512	24	Dark/Small
Kodak KAF0261E	1.0	744	22	1	512 x 512	20	Dark/Small
Kodak KAF1001E	6.0	1071	13	1	1024 x 1024	24	Dark
Sony ICX205AL	0.3	?	3	1MHz	1360 x 1024	4.65	Small
Sony ICX285AL	0.6	?	3	1MHz	1360 x 1024	6.45	Small
Canon EOS20D	3.4	3-30	≤ 10	ISO400	3504 x 2336	6.5	
DALSA/Teledyne	H2RG HyVisi	13.6	5-10	4	4096 x 4096	18	cryo only
Fairchild sCMOS	2.33	≤ 20	1.9	30 fps	2560x2160	6.5	

[†] Only 50% of (vertical) area used in frame transfer mode
^{††} Recommendations on comparable sensors welcome

Sensor requirements include:

• Sufficient (total) area to have enough guide stars

• Provide pointing error signal with $\sim 0.01''$ precision at ~ 1 Hz to telescope control system.

• Provide focus/alignment information between exposures to be used in hexapod corrections.

• Sufficient (total) area to have enough stars for wave-front sensing.

• Operate at ambient temperature to prevent heat dissipating within the field of view.

Several flow down requirements follow. Several of these are interrelated and a full trade study must be done for each sensor evaluated.

• Sensor area $\gtrsim 5 \text{ cm}^2 \sim 20 \text{ arcmin}^2$ to keep total sensor count low. Total guide area of $\gtrsim 10 \text{ cm}^2$ to ensure

• Signal to noise per star (SNR) of $\text{SNR} > 10$ with 10+ guide stars to provide required precision. Operation that is shutterless (frame transfer) with region of interest (dump drain for ignored rows).

• Colocation of guide and focus/alignment sensors.

• Prefer same sensor technology for focus/alignment to simplify design.

• Low dark current minimized at ambient temperature (AIMO, MPP, etc)

Many sensors were examined. The following table lists several of the sensors evaluated. The final column indicates the reason the sensor was not selected.

The baseline design utilizes an e2v ccd230-42-1-143. This sensor offers sufficient active area, the ability to operate in split frame transfer mode, four channel read-out and low dark current at ambient temperatures.

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Guide, Focus and Alignment Unit

Each guide, focus and alignment unit consists of

• Four sensors.

– Intra and extra-focal sensors measure the wave-front error.

– Two in-focus sensors provide the guide signal and seeing.

– Sensors operate in split frame transfer mode.

• Optical Filter.

– R band

– Defines apertures for active area of sensors

• Shutter

– Bonn shutter single blade design

BigBOSS focus/alignment unit.

Focus and Alignment

Conclusions

Acknowledgments

The system is designed to have sufficient area to have at least 10 guide stars even at NGP.